Nano galaxy

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A novel electrospun nanofibrous membrane that's out of this world

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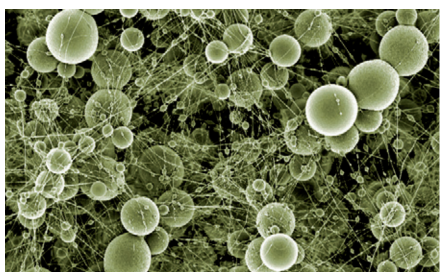
Water scarcity is gradually expanding as a global crisis all over the world. The reasons lie in water pollution and the dwindling of fresh water supplies. The optimum solution could be to introduce water filtration based on efficient membranes with low energy consumption. During the course of the last decade, efforts to create energy saving membranes for water treatment have increased tremendously and have recently employed systems that rely on nanofibrous structures.

Electrospinning is the most suitable technique for the production of nanofibers, due to its relative ease, low cost, high speed, vast materials selection and high versatility, allowing control over fiber diameter, microstructure, and arrangement. This technique is based on three main components: a high voltage supply, a capillary tube containing polymer solution/ melt attached to a needle of small diameter, and a metallic collector. To create an electrically charged jet of polymer solution/melt out of the needle, a high voltage is applied between two electrodes connected to the spinning solution/melt and to the collector (normally grounded). The electric field at the tip of the needle containing a droplet of the polymer solution electrifies the surface of the droplet. Repulsion between charges present at the surface, as well their attraction to the opposite electrode, creates a force that overcomes the surface tension and results in the ejection of a charged jet from the tip of the droplet. Due to the mutually repulsive forces of the electric charges in the jets, the polymer solution jet undergoes a bending instability and is elongated, becoming very thin. Meanwhile, evaporation of the solvent results in formation of a charged polymer nanofiber which is collected as an interconnected web on the collector.

The resulting web is composed of randomly aligned nanofibers resembling a non-woven material. Such a nanofibrous mat is highly porous and the interconnected pores are on the scale of a few times to a few ten times the fiber diameter. This promising structural feature makes the electrospun nanofibrous mats strong candidates for filtration applications as a membrane. The high porosity implies a higher permeability to fluid streams and the interconnected pores can withstand fouling better. Furthermore, the small pore size of the nanofibrous membranes could be beneficial in terms of providing high retention[1].



Despite an extraordinary permeability, due to the very high porosity and surface area, the nanofibrous membranes are susceptible to mechanical breakdown[2,3]. In addition, a combination of the hydrophobic membrane materials frequently used, a high surface area and the roughness could bring about a high hydrophobicity and fouling tendency. The restricted selectivity to only the microfiltration (MF) domain, i.e., the ability to discriminate only coarse suspended solids, is another drawback of this kind of membrane.

If electrospun nanofibrous membranes (ENMs) are to be produced on an industrial scale and produce real benefits, such shortcomings will have to be properly understood and addressed. This objective is one of the main research objectives of the Nanochemistry and Nanoengineering Group of the Institute of Polymer Research of Helmholtz-Zentrum Geesthacht. [3,4].

In term of selectivity, the ENMs possess a pore size in the range of microfiltration (100 nm – 10 μm)[2]. Hence, they are hardly able to catch particles below this range. To address such a problem, in one of our recent studies, an ENM was functionalized through protein immobilization. The biofunctionalized nanofibers could catch very tiny nanoparticles as small as 20 nm.[5]

This month's cover image is an SEM micrograph of an electrospun nanostructure composed of spheres (nano/ micro) and nanofibers that is being investigated for membrane applications. This "nano galaxy" structure is formed via electrospinning a dilute polymer solution. Indeed, an unstable charged jet of the solution creates a hybrid of nanofibers and spheres. This membrane possesses a novel nanostructure in which the spheres are assumed to limit the pore size, i.e., a more optimum selectivity.

FURTHER READING

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